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RESEARCH ON PEANUTS AND PEANUT PRODUCTS
AT THE SOUTHERN REGIONAL RESEARCH LABORATORY

BY: K. S. MARKLEY

SOUTHERN REGIONAL RESEARCH LABORATORY

New Orleans, Louisiana

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By K. S. Markley
Southern Regional Research Laboratory [2]
New Orleans, Louisiana

Most of this audience is acquainted with the history of the establishment of the regional research laboratories, of which the Southern Regional Research Laboratory at New Orleans is one of four such institutions. The establishment of these laboratories was authorized by Section 202 of the Agricultural Adjustment Act of 1938. Construction of the laboratory at New Orleans was begun in June, 1939, and the first unit was occupied in part in April, 1941.

The building is a U-shaped structure, the base of which is 211 feet long and 63 feet wide, and each of the two legs is 306 feet long and 66 feet wide. The administrative unit occupies the base of the structure, the laboratory wing which houses 72 laboratories occupies one leg and the pilot and textile mill occupies the other leg. In addition to the main building, there is a service building which houses the steam-generating equipment, ammonia compressors, incinerator, and other service utilities, and there is also a small building for storage of inflammable solvents such as alcohol, ether, petroleum naphtha, etc.

[1] Presented before the National Peanut Council Meeting at Atlanta, Georgia, May 2 and 3, 1944.

[2] This is one of four regional research laboratories operated by the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

Although fraught with constantly increasing difficulties in procuring the necessary laboratory and processing equipment owing to the impact of the war on

the manufacturers of this type of equipment, the laboratory and pilot plant are now reasonably well equipped for carrying out many types of research, not only on peanuts but also on other assigned commodities. Some of the larger pilot-plant processing equipment is still undelivered, some are still in the design and development stage, and some await the completion of laboratory work on which the pilot plant development is dependent.

As a preliminary step to the establishment of the four regional research laboratories, Congress provided that a survey be made to determine the nature and extent of the then current research activities on all agricultural commodities, to obtain suggestions for necessary additional research in this field, and to obtain such information as would be valuable in formulating a research program for the laboratories. The personnel of this special survey staff visited every state of the Union, and interviewed representatives of private and public research laboratories, educational institutions, and agricultural organizations. There was thus obtained a broad knowledge of the scope and nature of the current research activities in the United States, and also many hundreds of suggestions regarding the research needed on various farm commodities. Such information was, and will continue to be in the future, an invaluable aid in avoiding unnecessary duplication of efforts and activities and has served as a guide in the selection of many of the proposed research projects. The results of this survey were transmitted to Congress by the Secretary of Agriculture and published as Senate Document No. 65, 76th Congress, 1st Session.

At the time the laboratories were authorized and the survey was undertaken, large segments of American agriculture were burdened with tremendous crop surpluses and consequently suffered from depressed prices. Based on the results of the survey of existing research facilities and activities and especially with reference to the then existing surpluses, certain commodities were assigned to each of the

four regional research laboratories for investigation. The commodities assigned to the Southern Regional Research Laboratory were cotton, peanuts, and sweetpotatoes. The research work on these commodities is carried out in seven Divisions of which three are concerned with investigations on peanuts and peanut products, namely, the Oil, Fat and Protein Division, the Analytical, Physical Chemical and Physical Division, and the Engineering and Development Division.

The survey of existing research facilities and activities referred to above revealed the fact that no extensive research was in progress with reference to the industrial utilization of peanuts. Considerable agronomic work was being conducted both by the United States Department of Agriculture and the various state experiment stations; some nutritional work was in progress, especially with reference to the proteins and vitamins in peanuts and peanut meal; and a number of private firms were carrying on work on the utilization of peanut oil in such products as shortening, oleomargarine, cosmetic and pharmaceutical preparations and in certain minor specialties.

By far the most extensive investigations on all phases of peanut research were being conducted by the Georgia Agricultural Experiment Station and I am sure all of you are familiar with the series of informative publications which have resulted from that work.

The research program on peanuts at the Georgia Agricultural Experiment Station is soundly based and has been prosecuted as energetically as facilities, personnel, and finances have permitted. Dr. H. P. Stuckey, Dr. B. B. Higgins, Mr. K. T. Holley and Mrs. J. G. Woodruff and all the other individuals who have been responsible for, or had a part in this work, deserve much credit for their contribution to our present knowledge of peanut production and utilization.

At this point I want to say that the cooperation which the Southern Regional Research Laboratory has received from the Georgia Agricultural Experiment Station

in its research activities has been unstinted and highly gratifying as well as most helpful.

Aside from the agronomic work of the various agricultural experiment stations and the activity of the Georgia Agricultural Experiment Station mentioned above, little systematic work was in evidence. However, it is not improbable that other work in this field may have been in progress which did not come to the attention of those conducting the survey.

At the time the original research projects were being formulated (1939-40), peanut production had risen to 1,749 million pounds (1940) of which 558 million pounds were crushed for oil. Crude peanut oil production amounted to 171 million pounds (1940-41) and peanut meal to 130,000 tons. Benefit payments of one type or another were being paid to divert peanuts from edible channels to oil mills for crushing which was the only industrial outlet existing at the time. Of the total factory consumption of peanut oil, 75 to 90 percent was being consumed in the production of shortening and oleomargarine and all of the meal as feed for livestock.

These restricted industrial outlets were due in part to the lack of adequate knowledge concerning the inherent chemical and physical properties of the peanut *per se* and of its component parts, or to lack of processing facilities to adapt them to other uses. One example will suffice to emphasize this point. Peanut oil, owing to its comparatively high stability when properly expressed and refined, is an excellent oil for use in the manufacture of mayonnaise and salad dressings. However, an oil for use in these products must be either a natural "winter" oil or must be "winterized" to produce a "winter" oil. A natural "winter" oil is one, like corn oil, which does not solidify at ice box temperatures. Cottonseed oil, which is not a natural "winter" oil, can be winterized to produce an oil which will behave as a natural "winter" oil. Peanut oil cannot be winterized by the usual commercial winterization process because on cooling to a low temperature it tends to

produce a mushy product which cannot be separated by filtration. Because of this property of peanut oil, it is excluded from a relatively large market, - a market which last year (1942-43) consumed 225 millions of pounds of oil.

Information revealed by the research survey mentioned above, taken together with the then existing conditions relative to production and marketing conditions, and the obvious need for the development of new industrial outlets for peanuts, furnished the basis for formulating the original research projects on peanuts and peanut products. Work on these projects had scarcely started when the impact of the war and changing economic conditions necessitated a revision and modification of the research program. In certain respects the war emphasized and accelerated some phases of the original research program while others were minimized or rendered unnecessary. Adjustments were made in the program to adapt it to existing needs and minor changes have been made since then to keep it as close as possible in step with changing conditions resulting from the war effort.

The following report of the developments up to the present reflects the various changes which have been made during the past three years. This report which is necessarily greatly condensed is intended to show the nature of the problems which have been undertaken at the Southern Regional Research Laboratory and the progress which has been made.

Research work directed toward the industrial utilization of peanuts falls naturally into two distinct subdivisions, one involving the lipid or oily constituents of the kernel and the other the non-lipid constituents, i.e. the proteins, carbohydrates, etc. Each of these two subdivisions can be further subdivided into two other divisions, namely, the more fundamental laboratory investigations and the pilot plant or processing investigations. To some extent the laboratory investigations furnish necessary fundamental information on which subsequent pilot plant development work is based and the two have to be coordinated to produce the maximum

results.

MODIFICATION OF THE PROPERTIES OF PEANUT OIL.

A series of investigations were carried out to determine whether peanut oil could be adapted per se, or after treatment to modify its properties, as a substitute for certain imported oils which had been cut off as a result of the war. Among the oils in this class was olive oil which is prized in certain quarters for culinary purposes, and which has certain specialty uses, for example, in the textile industry, for which no other natural oil is entirely suitable.

It soon became evident that for most purposes the properties of peanut oil required modification (1). Various methods of accomplishing such modification include hydrogenation, low temperature solvent fractionation, molecular distillation, saponification and re-esterification, and interesterification.

Each of these processes and combinations thereof were applied with gratifying success. All of them can be carried out in equipment now available in the oil processing industry except low temperature, continuous, solvent fractionation. Neither laboratory nor industrial scale equipment was available which was adaptable to this operation, here consequently both the process and equipment had to be developed to accomplish this operation. A laboratory solvent fractionation or solvent "winterization" unit was developed which operated on the batch principle and which had a capacity of 1 to 2 pounds of oil per charge or approximately 1/2 gallon of solvent-oil mixture.

While this equipment was being developed and fabricated, the hydrogenation of peanut oil was being investigated to determine the effect of variables such as time, temperature, rate of agitation, hydrogen pressure and catalyst on the reaction products (2). It was demonstrated that peanut oil could be hydrogenated in such a manner that part of it resembled olive oil with respect to physical and chemical properties required for its use as a textile lubricant.

The next step involved the separation of the olive oil-like component of the hydrogenated peanut oil from the undesirable compenents. This step involved fractional crystallization at low temperature. In the meantime a process of solvent winterization was developed which made possible the winterization of peanut oil in about an hour and 15 minutes compared to 4 or 5 days for the present commercial winterization of cottonseed oil. In fact, it was found that either cottonseed or peanut oil could be winterized to yield approximately 80 percent of a winterized oil under approximately the same conditions. By the application of this process to peanut oil it is possible, therefore, to produce an excellent oil for use in the manufacture of mayonnaise and salad dressings or for general table use.

When properly hydrogenated oil was subjected to the same process, it was found possible to separate the olive oil substitute in approximately 78 percent yield. Samples of the oil were sent to various industrial concerns for examination. One sample was sent to the National Wool Manufacturers' Association who reported that the oil was not only equal to but superior to olive oil as a worsted lubricant (3).

The method of hydrogenation and solvent winterization was found to be applicable to the production of a number of other substitute fats including cocoa butter (4). Publication of the results of these two investigations was followed by the receipt of inquiries from 75 industrial concerns including 10 inquiries from 7 foreign countries, namely, Argentina, Brazil, Mexico, Uruguay, Canada, England and Switzerland. Most of the inquiries have been received from industrial concerns interested in the utilization of these products, but similar interest has been exhibited by a number of concerns in their commercial production. Practically all of the interested consumers were desirous of obtaining sufficiently large samples to permit trial applications in the particular product or process produced or operated by the inquirer. Other inquirers desired information on production costs and other processing details. Most of these requests could not be complied with owing to the small capacity of the

laboratory unit, consequently it was necessary to design a pilot plant unit with considerably increased capacity. Such a unit was designed and is now in process of fabrication. It is expected that within the next few months equipment will be available for producing these products continuously at a rate of 200 pounds per hour.

It was found that the olive oil substitute, which was developed as a textile lubricant, while excellent for the purpose was not as well adapted to sulfonation as olive oil. An oil suitable for sulfonation must possess a lower titer value than a textile lubricant. The required titer value cannot be obtained by hydrogenation and solvent winterization of peanut oil owing to the peculiarity in the natural distribution of the fatty acids in the glyceride molecules. In order to achieve the proper distribution, it is necessary to either split the fat prior to winterization and then recombine the winterized fatty acids, or to effect an intramolecular rearrangement of the fat by esterification. Conditions for effecting these reactions are relatively unknown, consequently experimental work intended to provide this information was undertaken. Many catalysts and conditions of operation were tried as a result of which it was ascertained that the chlorides of zinc and tin were most effective in promoting esterification. With the aid of these catalysts, esterification with glycerol can be completed in a reasonable time at a temperature between 175°-200° C. compared with temperatures of 225°-250° C. without a catalyst. The lower temperature and shorter time minimizes polymerization reactions and simultaneously produces more complete esterification and higher yields (5).

It has been found that an excellent oil for sulfonation can be produced by means of the esterification process by using peanut oil foots from the refining operation instead of high-grade refined oil.

STABILITY OF PEANUT OIL

Properly refined, or refined and hydrogenated, peanut oil possesses relatively good keeping qualities but eventually it undergoes oxidative rancidification like

other oils of its class. Also under certain conditions of use, as for example in deep fat frying and in finished edible products where the oil is exposed in thin layers to light and air, various forms of deterioration ensue. Work was undertaken to increase the stability of peanut oil and has been directed toward the isolation or concentration of the natural antioxidants in peanut oil and the determination of the effect of their addition in known amounts to fats like lard which are practically devoid of these substances.

Two methods have been used in producing these antioxidant concentrates from peanut oil, namely, molecular distillation and low temperature solvent fractionation (6,7). Other phases of this work have dealt with methods of improving the stability of peanut oil by addition of antioxidants to the oil and also with means of reconditioning the oil after it has undergone oxidative rancidification in various degrees (8).

RESEARCH ON PEANUT MEAL AND PROTEINS

The work on peanut meal and proteins can be divided into 3 categories as follows:

(1) Structure and composition of peanut proteins in relation to their possible industrial applications.

(2) Development of vegetable protein adhesives and sizes.

(3) Development of vegetable protein fibers.

(1) STRUCTURE AND COMPOSITION OF PEANUT PROTEINS: The development of a satisfactory and economical method of separating the proteins of peanuts requires a knowledge of the solubility of the component proteins. No information was available concerning the solubility behavior of peanut proteins as a function of concentration of the meal, pH, effect of salts, etc. Using solvent-extracted peanut meals prepared under conditions designed to minimize denaturation, data were obtained on the percentage of extractable protein at various meal-water ratios, pH values (both acid and alkaline ranges), and specific salt concentrations. These results made it

possible to define the optimum conditions for recovering the maximum yield of specified protein products from solvent-extracted meal. However, since there is no commercial source of solvent-extracted meal at the present time, it was necessary to repeat the work with commercially available hydraulic pressed meals. The results of this work have been published in a series of three articles (9, 10, 11) which may be briefly summarized as follows:

Seventeen commercial peanut meals were investigated with respect to the extractability of the protein as a function of the residual oil in the meal, pH (acid and alkaline range) of the solution, concentration of sodium chloride and sodium sulfite, etc. Comparison was also made on the color of the recovered protein as a function of the method of recovery, and of the presence or absence of skins in the meals. Red skinned varieties of peanuts, both blanched and unblanched, and also unblanched white skinned varieties, were investigated. Wide differences were observed in the protein solubility of meals from various commercial mills. Some pressed meals were found which possessed protein solubilities nearly as great as that observed with solvent-extracted meals while others were nearly insoluble by comparison. The processing factors which were primarily responsible for changes in protein solubility were heat, humidity, and length of treatment during the cooking and pressing operations. The critical denaturation temperature as measured by peptization was found to lie above 118° C. (244° F.) dry bulb and 80° C. (176° F.) at 100 percent relative humidity. Pressing conditions compatible with minimum denaturation of the protein of the meal are within the range of mill operation with respect to good yields of oil but apparently are not followed judging from the degree of denaturation observed with the majority of meals examined. Probably an even worse situation results from the fact that such conditions as are employed in the average oil mill are not controlled but vary from day to day even in the same mill.

White skinned varieties of peanuts were not found to differ significantly from red skinned varieties with regard to their protein solubility, and storage for two years before removal of the oil did not appreciably alter the extractability of the protein. The color of the extracted protein was best in the case of white skinned varieties; poorer in blanched, red skinned varieties; and worst in unblanched, red skinned varieties.

It was subsequently observed that peanut meal behaved quite dissimilarly with respect to its solubility in various types of acid media which necessitated investigating this product with a number of different acids over their entire pH range. The most marked differences were observed with the solubility of peanut protein in hydrochloric and sulfuric acid solutions at the same pH. At pH2, for example, hydrochloric acid extracts about 80 percent of the protein from peanuts compared to 25 percent for sulfuric acid.

Other work on the nature and properties of peanut proteins has included fractionation of proteins to determine the number of individual proteins present, the amino acid composition of the isolated proteins, and an investigation of the carbohydrates which are associated with the protein in the seed. The work on protein fractionation has led to the separation of several individual proteins which are being further investigated by electrophoretic methods at the Eastern Regional Research Laboratory and by ultracentrifugation at the Western Regional Research Laboratory.

(2) DEVELOPMENT OF VEGETABLE PROTEIN ADHESIVES AND SIZES:

Considerable success has attended the development of adhesives from peanut proteins and meals, especially of tacky and re-wettable types. The market for re-wettable glues is enormous as is attested by the fact that one plant in which we have carried out tests with products made at the Southern Laboratory produces seven carloads of gummed tape a day. Several experimental batches of peanut protein glues

have recently been used in the manufacture of gummed tape under normal operating conditions in one of the largest gummed tape plants in the United States. These glues compared favorably with animal glues and for certain special purposes were superior to animal glues. For example, experimental batches of peanut glues gave adhesive test values as high as 75 by the Harnden McLaurin gummed tape tester compared with 92 for standard animal gummed tape glue. By comparison no vegetable protein glue, commercial or experimental, examined by the same firm has ever given any reading whatever on the Harnden McLaurin tester. The high test glue was made with protein from commercial, hydraulic-pressed meal. Advantages of the gummed tape glues prepared from peanut protein are: (1)Light color especially when applied to white paper; (2) Less hygroscopic than animal glues (3) More sanitary product than animal glue which is made from non-edible packing house wastes.

Flexible glues have been developed from peanut protein which have shown good performance in application and service in gluing paper covered boxes and which will shortly be tested for their applicability in book binding. Although a large number of glues have been prepared and tested for gluing wood joints, these have been less satisfactory than the flexible and re-wettable glues. Some of the wood glues made from peanut protein have been equal to presently available glues but not superior to them.

The successful development of the glue products mentioned above has depended primarily on the development of methods of obtaining suitable protein preparations from meal and a knowledge of the viscosity behavior of protein solutions. The first problem was solved by the development of a fusible protein, a product which is unique among protein preparations. It was observed that when a protein was isolated at its iso-electric point in combination with exactly the amount of water equal to its combining capacity for water, i.e., an iso-electric protein hydrate, the product was fusible at relatively low temperatures (40° to 50° C.). This iso-electric

protein hydrate melts to a clear liquid and solidifies again when the temperature is lowered. If the pH of the iso-electric protein is then altered in the proper direction the protein remains permanently liquid. This product furnishes the basis for a considerable number of unusual protein products.

The method of preparation of this protein hydrate is covered by a patent application and several of its industrial uses are covered in additional patent applications.

The application of all of these protein preparations as well as other vegetable proteins is dependent on a knowledge of the viscosity behavior of these products in solution which strangely does not appear to have been previously investigated. In order to determine the factors which influence the viscosity of protein solutions, it was necessary to make many hundreds of viscosity determinations with a wide variety of protein preparations. As a result of this investigation, it has been possible to define and describe the conditions which make possible the preparation of protein solutions having optimum and reproducible viscosities required for specific applications. The results of this investigation are contained in an article entitled: "Viscosity Patterns of Peanut Protein Solutions" (12).

(3) DEVELOPMENT OF PEANUT PROTEIN FIBERS: Just prior to the outbreak of the war in Europe there was developed in England a wool-like fiber of peanut protein known as "Ardil." The development was carried through all of the processing stages up to and including the weaving of cloth. The product appeared very promising and no doubt has been further improved, but so far as is known it has not entered commercial production probably owing to the fact that peanuts are imported into England from India and West Africa, and are now in demand for food and feed use.

Similar work was undertaken at the Southern Regional Research Laboratory but with the idea of producing a somewhat different type of fiber. It was found that

a fiber equal to or superior to soybean and casein fibers could be produced from peanut protein but pressure of other projects has not permitted the concentration of effort on the fiber work commensurate with the promise it holds forth.

GRADING, ANALYSIS, AND PHYSICAL PROPERTIES OF PEANUTS AND PEANUT PRODUCTS.

In cooperation with the Office of Distribution, War Food Administration, an extensive series of analyses of peanut kernels was made to determine the relationship existing between U. S. Standards for Farmers' Stock Peanuts and their chemical composition.

Data based on samples from the 1942 crop indicate that the most immediate measure of intrinsic value of market lots is the percentage of total sound mature kernels contained in the sample taken. Relatively small standard deviations were found in the percentages of oil and nitrogen of peanut kernels of a given commercial type of good to fair quality, (U.S. No. 1, U.S. No. 2, and U.S. No. 3 Farmers' Stock grades), grown under similar environmental conditions. It was observed that damage to kernels must be observably very serious to materially increase the free fatty acid content of the oil (13).

In order to adapt peanut oil to various processes and products, or secure to it special market outlets, data are required with respect to its thermal, dilatometric, and plastic properties, its solubility in various organic solvents, and many other physical and chemical properties. Practically nothing is known concerning these properties and it has, therefore, been necessary to determine as many of them as time and facilities permit. Some of this work has been completed, some is in progress, and some has had to be deferred until after the war when work now in abeyance can be taken up again.

One of the first investigations on the properties of peanut oil involved the determination of the smoke, flash, and fire points in order to determine whether or

not this oil possessed superiority over other oils with respect to these properties. Unfortunately, the results of this work were negative as far as these properties were concerned. It was found that the smoke, flash, and fire point of peanut oil, as well as cottonseed and other oils examined at the same time, were a function of the extent to which free fatty acids were present in the oil rather than to any inherent quality of the oil itself. (14).

Another example of this type of work may be mentioned, namely, a systematic investigation of the influence of iodine number and temperature on the viscosity and density of refined and hydrogenated peanut oils which was carried out to obtain essential data for use in designing oil processing equipment (15).

It was observed in the course of numerous analyses of various peanut products that many of the methods described in the literature were unreliable and required modification or development of entirely new methods. One example of these methods is the Renard and Kerr tests for the determination of peanut oil (16), others pertain to the determination of certain amino acids in the meal. Three investigations on as many methods led to means of improving the accuracy of two of them.

PLANT PROCESSING INVESTIGATIONS

The original research program contemplated extensive engineering investigations on the improvement of present processing methods and development of new methods. This plan has not been strictly adhered to owing to inability to obtain much of the required equipment and because of the diversion of engineering personnel to other problems more closely related to the war effort. One of these projects contemplated the investigation of solvent-extraction of peanuts to increase the yield of oil and for the production of relatively undenatured meals for industrial use. Until very recently, equipment for the continuous solvent-extraction of peanuts was not available but a pilot plant unit is now on hand and in process of erection. The necessary distillation and oil and solvent recovery equipment is in operation and has been

used in connection with batch extraction for the production of the solvent-extracted meal required in the above-mentioned protein investigations.

A complete oil refinery has been assembled and is in process of erection. Hydrogenation equipment, fat-splitting equipment, and a high temperature reaction kettle have likewise been received and are being erected. A complete protein processing plant has been designed and portions of it have been received. By the end of the year it is expected that all of the facilities for the complete processing of peanuts, peanut oil, and peanut meal will be available and in use.

Despite the length of this review of the research on peanuts and peanut products, reference to much of the work completed or underway has had to be omitted, but it is hoped that some idea has been conveyed of the ultimate contribution which this work may make to the future development of the peanut as an agricultural crop and as an industrial raw material.

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